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MOENJODARO: A WORLD HERITAGE SITE AT RISK

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ABSTRACT

The aim of this paper is to describe the main threats affecting Moenjodaro, an archaeological site that prospered from 2350 to 1800 BC in the fertile Indus flood plain of Sindh (Pakistan). The major hazard is today represented by soluble salts attack (mainly sodium sulphate), rising damp, heavy precipitation in the monsoon season, poor drainage, thermal stress causing walls to lean and decay structurally, visitor behaviour, site mismanagement, and the lack of vegetation. As a result of poor conservation and bad management, in the year 2000 the site was inscribed in the ICOMOS register of heritage at risk. The paper analyses past and present conservation methods, and provides recommendations for future repair and maintenance.

Keywords: *Conservation, archaeological sites, rising damp, fired brick, salts weathering, Pakistan*

1. HISTORY OF THE SITE

1.1 Moenjodaro and the Indus Valley Civilization

The archaeological site of Moenjodaro is located 32 km south of the city Larkana in the region of Sindh, Pakistan. Because of its proximity to the river Indus and the similarity to other sites, scholars and archaeologists refer to it and to the site of Harappa as the epicenters of the Indus Valley Civilization (Figures 1-3). This spread from the Suleiman and Kirthar mountains, from the Arabian Sea to the foot of the Himalayas, whilst evidence of trading activities were also found as far as Mesopotamia, Bahrain, and the Gulf.¹ The Indus Valley Civilization, now represented by about 1500 sites in an area of half a million square miles, was remarkably sophisticated in terms of town planning, provision of public water and sewage systems, and this is especially true for Moenjodaro. The site flourished in the early Bronze Age (third millennium BC) and the reasons for its abandonment are unknown but may be due to the regular flooding of the river. The site was built mainly of fired brick and mud mortar, but mud brick was also employed for the construction of platforms on which fired brick dwellings were built (Figures 4-6).

1.2 Moenjodaro's recent history

Since 1924, when it was first excavated by the Archaeological Survey of British India under Sir John Marshall, the site has suffered from unceasing decay due to both environmental and man-made factors. In 1972 the Government of Pakistan and UNESCO jointly prepared a master plan for the conservation of the site. It is believed that only 10% of the 240 hectares of the archaeological remains of Moenjodaro are actually excavated. The Prohibition that is presently in effect will be lifted when conservation of the excavated structures has reached the level of routine maintenance.² One of the main events that recently most heavily affected Moenjodaro was the construction of the Sukkur Barrage, as explained by Miyagi and Tabata:

'Sukkur Barrage, the largest irrigation dam in the Indus valley, was constructed 120km upstream from the site of Moenjodaro in 1933. It enabled the middle basin of the Indus valley to be irrigated for agricultural development, with rice cultivation prevailing in the area but activated the rise of the ground water-table which deteriorated the remains through salinization. Also, the full operation of the Sukkur Barrage influenced the flow of the river Indus and its main course shifted further west towards the site, making the flooding of the river one of the main threats for the site conservation.'³

Since 1964 experts and consultants have carried out several technical missions on behalf of UNESCO with the aim of studying the mechanisms of decay and of proposing appropriate conservation methods.⁴ In the 1970s the Moenjodaro campus was built near the site, housing several buildings, amongst which are the Water and Soil Investigation Laboratory (WASIL), a museum, a guest house, accommodation for employees, offices, storage rooms for conservation material, offices for the Moenjodaro preservation authority, a tourism office, police station, mosque, and post office. The WASIL laboratory was set up with the support of UNESCO with the aim of carrying out analysis of conservation material, water, soil, and to collect feedback data on conservation measures.⁵

In 1980 the site was inscribed in the World Heritage list. Between 1992 and 1997 the Japanese Fund-in-Trust for the Preservation of the World Cultural Heritage financed the conservation of Moenjodaro. The outcome was the master plan that was prepared in 1972 and revised in 1997 and that is still in use today.⁶ Its key objectives are: river training, ground-water control, conservation of structural remains, plantation of salt-tolerant vegetation, landscaping, and cultural tourism. In the year 2000 the site was inscribed in the ICOMOS Heritage at Risk register with the following justification:

'In spite of all activities and international support, it seems that the Pakistan Government has difficulties to keep up scientifically with the continuation of the conservation and maintenance plan. The programme suggested by UNESCO, being regular control of the salt-endangered surfaces plus mud-brick conservation, does not seem to be executed to the needed standards.'⁷

In 2005 the Moenjodaro Conservation and Research Centre (MCRC) was established as a management structure for the site. This was dismantled after one year and at present the organization responsible for the conservation of the site is the Department of Archaeology and Museums (Ministry of Culture, Sports, and Youth Affairs).

1.3 Building Materials

Mud brick

Moenjodaro's historic mud bricks measure 10 x 20 x 40cm and were mostly employed for the construction of massive platforms on which fired-brick dwellings were built. There is no study at present that explains how the Moenjodarians manufactured mud bricks. The study of past craftsmanship involved in construction of the earthen platforms is of great importance for the structural stability of the fired-brick ruins, but no archaeological investigation has delved into this. While it can be assumed that mud bricks were manufactured with local soil there is no evidence on the use of additives or straw.

Fired brick

Moenjodaro's historic fired bricks measure 6.3 x 13.4 x 27.9cm. There is no proof on how fired bricks were manufactured in the third millennium BC but it is likely that the methods employed did not differ much from those in use today (Figure 7). The area around Moenjodaro is scattered with kilns for firing bricks that use a mix of mix of loam, rice-husk ash, sand and water as raw materials. Similarly to practices in Britain in the Middle Ages, ashes are necessary in the mix '...so that the green bricks provide some of their own fuel'.⁸ The mix is tramped by feet and left to rest before moulding. After drying, the green bricks are stacked to form clamp-kilns that are roughly rectangular in form. Rice husk is employed for kindling and the firing continues for up to four days.

The use of such bricks in conservation is unproblematic in some ways since they are easily identifiable as new because of their size, measuring 5.1 x 11.4 x 22.9cm, and have a characteristic frog which is missing in historic bricks. However, little attention is paid to whether the clay that is employed for their manufacturing is actually salt-free. Quality control of repair materials is mostly carried out to the clay used for slurring and repointing.

2. CAUSES OF DECAY

2.1 Soil salinity

In Moenjodaro the phenomenon of soluble salts decay takes place in a twofold way:

- Subsoil water is driven upwards by capillary action through the structures and in so doing it carries soluble salts. Such salts effloresce on the brick surface if the evaporation is slow, and sub-florescence if the evaporation is fast (Figures 8 -11).
- Hygroscopic salts, such as sodium sulphate, draw water from the air and are put in solution.⁹ Phenomena of hydration and dehydration occur because of temperature cycles, and this creates great pressure for both brick and mortar that tend to powder in response. If the evaporation is slow not only does powdering take place, but also chunks of bricks fall apart.

During the winter, salts tend to crystallize mainly on the northern and western elevations and sometimes on the eastern faces when in shade because the favorable temperature for crystallization is 32 degrees C. In the summer the phenomenon takes place within the brick fabric with the result that masonry tends to spall (sub-florescence). Mud slurry is the best and least expensive remedy for protecting fired bricks from salts weathering¹⁰. Furthermore, mud plaster is effective against sub-florescence as it can minimize heating of the structures to some extent. The data provided in Table 1 show that the most common salts are sodium, potassium, calcium, magnesium, carbonate, bi-carbonate, nitrate, nitrite, chloride and sulphate, with sodium sulphate and sodium chloride found in abundance. The analysis on Table 1 further shows that the amount of salts decreases with the increase in depth, which suggests that their concentration is higher at the surface due to evaporation.

2.2 Rising damp

The decay caused by rising damp is directly connected to the soluble salts content of both sub soil and water. Irrigation of farmland around the site contributes to the rise of the water table, thus affecting the structures.¹¹ Other factors that encourage rising damp include the difference between excavation levels, structures with only one side excavated, and the higher level of the river Indus bed. Ground level at Moenjodaro is 47 metres AMSL whereas river Indus flood level is 50 metres AMSL. Furthermore, the Dadu canal flows at 47 metres AMSL, almost the same level as the site. It should also be mentioned that the sub-soil water fluctuates between 41 and 45 metres (AMSL) throughout the year, meaning that the sub-soil water level remains almost constant at two metres below the surface. Miyagi and Tabata explain that: 'It is reported that the ground water level in the area was 7.6m below the surface in 1922. It rose to 4.9m in April 1949, and 1.5m in May (rainy season) and 3.7m in October (dry season) of 1964. The primary cause of such change was agricultural

irrigation water as supplied by the Sukkur barrage through the Dadu canal.¹² In 1985, in order to lower the water table, tube-wells were installed and a disposal channel was constructed (Figure 3). The tube-wells were positioned along the concentric collector drain so as to cause as little harm as possible to the structures, and drilling was done to an average depth of 75.5m below the surface. The water table was lowered to 5.8m below the surface in the rainy season and to 8.5m in the dry season.¹³ At present the tube-wells are not working and overall this project did not prove to be successful against rising damp and efflorescence because salts, being hygroscopic, collect dew from the air.

2.3 Monsoon precipitation and poor drainage

Monsoon rain is one of the main causes of masonry decay. Fired brick structures tend to be eroded and settle when precipitation is combined with poor drainage (Figure 12). Precipitation concerns the structures at two levels. The erosion of mud mortar, mud-brick capping, and fired-brick masonry is deeper in the top portion. The lower portion is affected by ponding due to water mismanagement and this contributes towards the rising of dampness. Rainwater mostly affects the site from the north and it should also be mentioned that splashing plays a role in the decay of mud mortar. Due to the topography of Moenjodaro's excavations it is quite complicated to drain out water from the site. However, the effort made by MCRC in 2005 proved to be effective and drainage was improved in several areas. Proper topographic survey is essential for the recovery of drainage system, and this is still to be carried out in Moenjodaro. Water needs to be drained slowly as fast drainage causes gullies and holes. In this sense the employment of barriers of sun-dried bricks proved to be effective for the slowing down of rainwater flow and hence for reducing soil erosion.

2.4 Structural decay caused by thermal stress

Temperatures of more than 60 degrees C were recorded on fired-brick walls exposed to the sun, and experimental analysis shows that this value significantly drops at a depth of 3mm from surface.¹⁴ Diurnal fluctuation of temperature is 20 degrees C, whilst seasonal fluctuation can be between 4 and 46 degrees C. Direct inspection reveals that the lean of walls derive from thermal movements as the majority of structures that are not connected, and are therefore free to move individually, tilt towards the colder side (north and west). Out-of-plumb walls are a severe problem in Moenjodaro especially in the monsoon season and when proper drainage is not ensured. Furthermore, it was suggested that microfractures may be another result of thermal stress and that these may provide further pore-like structures where salts may crystallize.¹⁵

2.5 Man-made damage

Man-made damage is represented by inappropriate past conservation measures and by site mismanagement. Numerous disrepairs were carried out on several structures in the recent past and a full description of the extent of the damage is provided by Fodde.¹⁶ Inadequate conservation measures were carried out in the past before MCRC due to a lack of scientific control. This includes the insertion of damp-proof courses made of precast concrete slabs coated with bitumen to block capillarity rise of water, a practice that was carried out until 2001. This is due to the conventional and simplistic idea that 'strong' materials should be used. The resulting consequence was that many structures were heavily damaged.

2.6 Lack of vegetation

Compared to other conservation tasks mentioned in the Master Plan, plantation was given a low priority because not considered urgent and is still neglected today. Between 1994 and 1997¹⁷ the Forest and Wildlife Department (Government of Sindh) undertook a study of the flora of Moenjodaro and a new survey of the native species was completed in 2005 as part of the MCRC management (Table 2). It is clear that in the photosynthesis process indigenous plants use salts in the form of ions that are transported to the leaf stems. Native vegetation thus has the ability to tolerate salts. The

growth of plants is thus also affected by the presence of salts and hence their analysis is necessary at different depths. In this context it is important to know the water profile (water table) and the soil profile (grain size distribution and percentage of salts). It is therefore suggested here that as a future task soil samples are taken at the following depths: surface, 20cm, 50cm, 100cm, 150cm, 200cm, and then with an interval of 50cm down to a depth of 4.50m (overall 11 samples for every hole). Previous research has shown that salts concentration is higher in the first metre from the surface and this was demonstrated after taking temperature readings and showing that temperature is constant after 1m.

The botanical survey of 2005 was undertaken with the quadrat sample method. The 48 surveyed areas measured 100 x 100m each and locations were selected at random. The results were then averaged out to the whole area under examination. An important reason for carrying out the future plantation is provided by Miyagi and Tabata who explain that:

'The windbreak of green belts would be developed considering several factors such as wind direction, density of planting as well as composition of plant species. The species adaptable to this environmental condition are *Tamarix*, *Prosopis*, *Acacia*, *Populus*, and *Eucalyptus*. It is recommended that shrubs of *Salvadora*, *Agave*, *Capparis*, and *Haloxylon* and other grass species tolerant to the salinity are planted to make the wind break effective enough.'

3. CONSERVATION OF STRUCTURAL REMAINS

Several conservation treatments are in place at Moenjodaro. The list supplied here describes the methods that proved to be effective after decades of practice:

- Construction of fired-brick buttresses for the consolidation of leaning walls and for preventing collapse. Brickwork is laid with no mortar so as to make the intervention readable as new.
- Mud-brick *pushtas* for the consolidation of heavily eroded structures at base level. Such low buttresses surround the wall base in a stepped pattern so as to act as a protective cover against coving.
- Capping with mud brick as a protection against heavy precipitation and thermal stress.
- Mud-slurrying as sacrificial coat against salts attack (Figures 13 and 14). Structures that are heavily affected by salts crystallization are treated with mud-poulticing and mud-plaster.¹⁹ However, despite being effective against efflorescence, this technique does not prove to be useful against sub-florescence.
- Repointing is carried out not as cosmetic measure, but for consolidating those structures that lack bonding. Silty soil is employed as mortar and no other additives are used.
- Improvement of drainage and replacement of salt-affected soil. The second is necessary to reduce the extent to which ground salts affect the structures through capillary action.

Two types of soil are employed in the conservation of Moenjodaro: clayey and silty soil. Clayey soil is employed for slurrying, drainage, and masonry work. Silty soil is used for wall capping and the creation of shallow ponding. The grain size distribution of such soils and their granulometry curves are provided on Figures 15 and 16.

4. CONCLUDING REMARKS

The aim of this section is to draw some conclusions in the form of final statements and recommendations:

- A more comprehensive study of the archaeological evolution of building techniques of Moenjodaro is yet to be assembled. There is a strong need for research which could gather and review all of the scattered available information. The creation of a broad corpus of work on building archaeology would undoubtedly provide lessons for future conservation initiatives.
- In order to minimize crystallization of soluble salts on fired brick, it is suggested that selected structures be shelter-coated with mud bricks. This experiment should be carried out with mud bricks set on edge over a 10cm layer of sand, and the structure be conserved before being

treated with the shelter coat. This may include repointing, replacement of decayed brick, construction of buttresses for leaning walls and improvement of drainage.

- Mud-poulticing and mud-slurrying is essential for overcoming the problem of salts as crystallization occurs on the sacrificial coat rather than on the brick face.²⁰ However, it is essential that a monitoring system is developed and carried out.
- The agricultural land around Moenjodaro has high salts content and this is increased by the irrigation system: fields are inundated with water for weeks and this makes the water table rise (see Figure 4 for proximity of fields to the site). As a result water tends to migrate towards the structures and salts crystallize on the surface. There is an urgent need to stop the cultivation of paddy crops to overcome the problem.
- Proper scientific investigation should be carried out to discover mechanism behind the leaning of walls. On the basis of such scientific analysis, leaning walls should be provided with proper support and a monitoring system should be put into place.
- Similarly to what done in other sites, conservation interventions should be carried out after extensive laboratory analysis so as to ensure suitability of repair materials and methods.²¹
- The inscription on the ICOMOS Heritage at Risk register has not produced any effective measures against the continuous decay of the site and the proposals made by UNESCO are not entirely put into practice. Furthermore, it is essential that documentation is carried out before and after conservation and this needs to be seriously improved in Moenjodaro.

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Table 1: Analysis of soil samples, bore hole 1 (located near MD15). The general trend is that salts content increases towards the surface. However, since subsoil strata changes with layers of sandy and silty soil, salts concentration varies accordingly

Depth (cm)	TDS (mg/l)	Conductivity (µs/cm)	SO ₄ (mg/l)	NO ₂ (mg/l)	NO ₃ (mg/l)	Ca (mg/l)	HCO ₃ (mg/l)	CO ₃ (mg/l)	Cl (ml/l)	Mg (mg/l)
0	9.2	18.4	370	6.1	17.6	11.5	2.2	present	59.8	19.9
20	4.5	8.2	280	0.8	16.3	12.5	2.5	nil	38.2	16.0
50	3.3	6.2	540	0.2	13.6	8.3	2.3	present	36.3	12.5
100	2.3	4.5	410	0.5	10.3	0.9	3.4	present	28.8	1.2
150	1.6	3.1	400	0.1	11.0	0.7	3.5	present	20.5	1.3
200	0.8	1.6	140	0.4	7.5	0.7	3.4	present	9.4	1.2
250	0.7	1.4	70	0.6	11.9	0.9	3.7	present	7.8	0.5
300	0.9	1.7	140	0.7	7.0	0.7	3	present	8.6	0.8
350	0.6	1.2	220	0.7	15.0	0.8	6.8	present	7.4	0.8
400	0.7	1.4	190	0.4	11.9	0.9	5.3	present	6.4	4.2
450	0.9	1.8	530	0.6	9.7	0.9	5.2	present	9	4.9

Table 2: Result of the flora survey as carried out in 2005

Botanical and Sindhi name	Description	Percent
Acacia nilotica (Babul)	Tree	5.9
Albizia lebbek (Siris)	Tree	0.5
Alhagi camelorum (Kandero)	Undershrub	7.6
Azadirachta Indica (Neem)	Tree	0.5
Capparis aphylla (Kirir)	Low shrub	1.1
Conocarpus (Cono)	Tree	1.6
Desmostic bipinnulata (Drub)	Grass	18.4
Eucalyptus camaldulensis (Eucalyptus)	Tree	5.4
Palm (Khaji)	Tree	1.1
Prosopis cineraria (Kandi)	Large shrub	6.5
Prosopis juliflora (Mesquite)	Large shrub	7.6
Salsola foetida (Lani)	Shrub	5.4
Salvadora oleoides (Khabar)	Shrub	22.2
Tamarix dioica (Lai)	Shrub	16.2

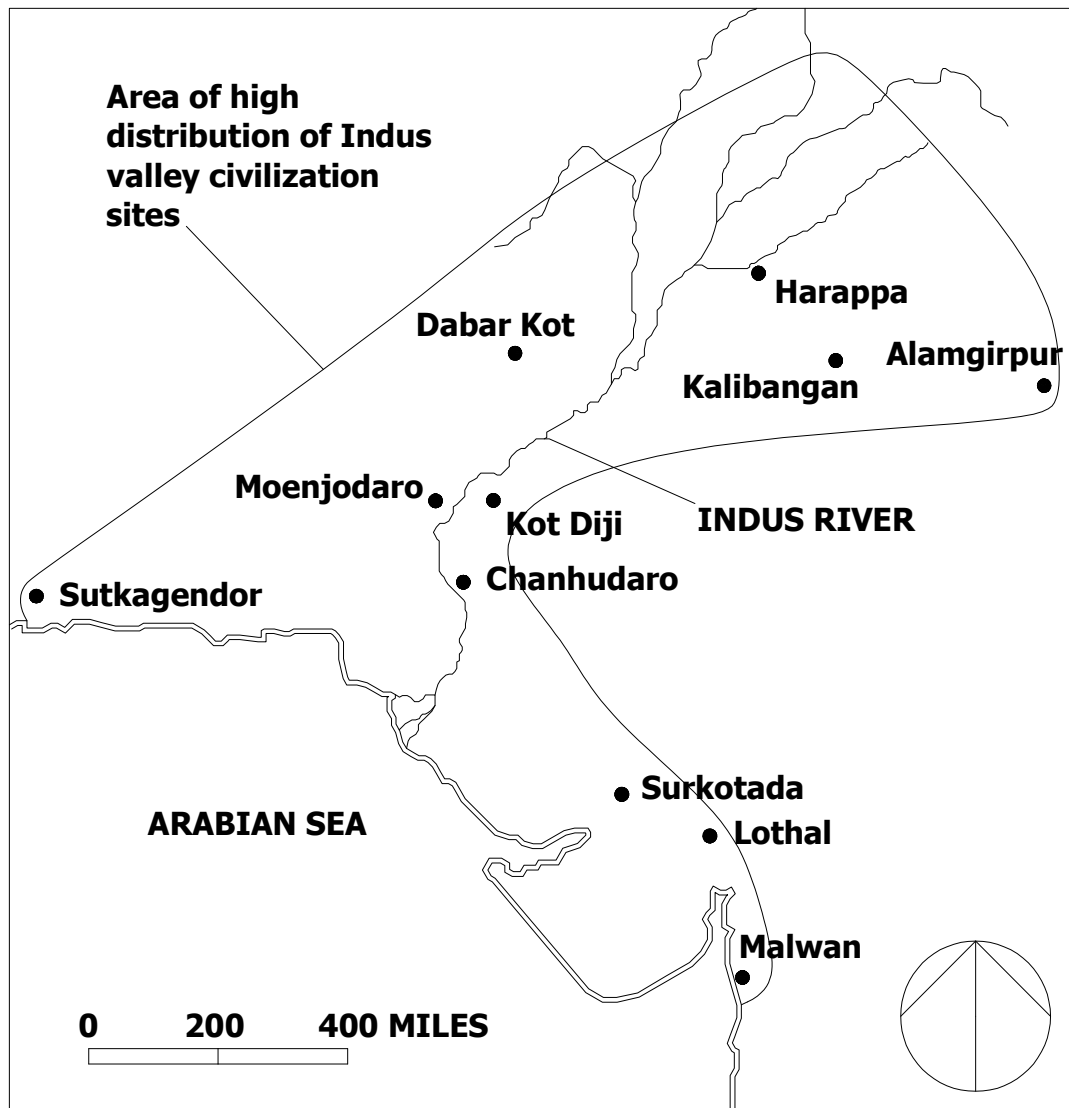


Figure 1: Geographical distribution of the Indus valley civilization (after Masatoshi, 1994)



Figure 2: Satellite picture of the site of Moenjodaro (2003) showing lack of vegetation between excavated areas (see also Figure 3)

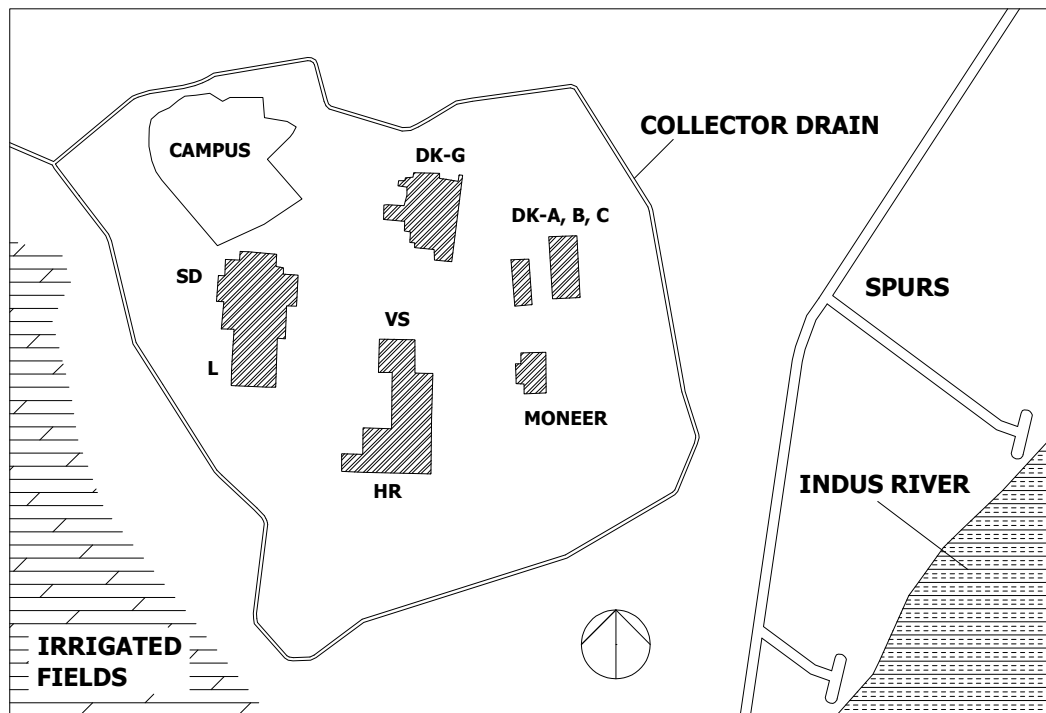


Figure 3: Schematic plan of Moenjodaro with extent of excavated areas



Figure 4: View of SD area with mud brick stupa



Figure 5: View of DK-G area showing typical narrow alleys



Figure 6: The stupa is constructed with a fired brick stepped platform to which a mud brick drum was added



Figure 7: Clamp kiln in the outskirts of Moenjodaro showing brick drying and firing.



Figure 8: Picture showing DK-G area with salts affected soil



Figure 9: Soluble salts attack, Main street, DK-G area



Figure 10: Close up of salts attack showing that when crystallization occurs below the surface (subflorescence) damage occurs



Figure 11: Sodium sulphate crusts as collected from one of the walls of DK-G

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- ¹ Shaikh & Ashfaq 1981, 10
- ² Briscoe 1997, 5
- ³ Miyagi & Tabata 1992, 8
- ⁴ Baloch 1978; Boekwijt 1979; Briscoe 1997; Hughes 1996; Yamada 1997; Khan 1998; Khan 2001a
- ⁵ e.g. Khan 1998
- ⁶ Yamada 1977
- ⁷ Jansen 2000, 152
- ⁸ Brunskill 1990, 27
- ⁹ Goudie 1977; Khan 2001a
- ¹⁰ Khan 1992
- ¹¹ Hughes 2008, 27
- ¹² Miyagi & Tabata 1992, 11
- ¹³ ibid
- ¹⁴ Briscoe 1997, 17
- ¹⁵ ibid
- ¹⁶ Fodde 2007a; 2008b
- ¹⁷ Baloch 1978
- ¹⁸ Miyagi & Tabata 1992, 15
- ¹⁹ Khan 1993
- ²⁰ Khan 1993
- ²¹ Fodde 2007b; 2008a